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RESEARCH

Beneficial Impacts of Chokeberry and Tart Cherry Based Dietary Supplements Consumption on Cellulite Reduction

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Abstract

Cellulite is an aesthetically distressing skin condition occurring in 80–90% of females and manifesting as dimples and depressions, producing an uneven surface to the skin. Our aim was to evaluate the effect of combined oral consumption of two dietary supplements based on chokeberry and tart cherry juices over a period of 32 days on cellulite reduction. Twenty women aged 21–49 with a cellulite grade of 1–2 according to the Nurnberger–Muller scale were participating in the study. Ultrasonography was applied to analyze the skin structure in addition to biochemical and anthropometric parameters, which were measured before starting the treatment and after 32 days. A reduction in the thickness of the dermis with subcutaneous fat tissue, subcutaneous fat tissue alone, epidermis, and dermis with epidermis (15.02, 14.34, 21.98, and 20.94%, respectively) was noticed, while the length of the fascicles was reduced by 35.93%. Out of 20 subjects, 11 (57.9%) had edema of the dermis at the beginning of the study, which was not recorded at the end of the study. Moreover, a statistically significant increase in the tissue doppler (TD) signals was recorded in all subjects treated with two dietary supplements, indicating a better blood supply. Changes in anthropometric and biochemical parameters were not recorded. Creatinine, urea, ALT, and AST values, as indicators of kidney and liver function, remained at normal reference levels, pointing out the product's safety. The positive effect of chokeberry and tart cherry juice-based dietary supplements consumption in cellulite condition could be connected with microcirculation improvements.

Keywords Cellulite Chokeberry Tart Cherry Edema Fascicles TD Signals

Introduction

Cellulite, or gynoid lipodystrophy, is a typical problem for women, affecting 80–98% of the postpubertal female population, whether they are obese or not [1]. It is characterized by dimpled skin alterations and is usually called "orange peel", so it is of significant importance for esthetic medicine [2]. Cellulite predominantly affects the thighs and buttocks, rarely the abdomen and lower legs [3]. Although the etiology of cellulite is not entirely understood, it is multi-factorial and connected with genetic, endocrine, and structural factors [4, 5]. It was reported that key roles in cellulite pathophysiology play diminished microcirculation, weakened connective tissues, and enlarged fat cells [2], whereby all of these disturbances are closely related to oxidative stress, a cell state represented as an imbalance between the production of oxidants, reactive oxygen and nitrogen species, and the antioxidant defence system capacity [6]. Namely, on the basis of proteomic analysis, it was established that a high degree of free radicals and aldehydic lipid oxidation products (4-hydroxy-2-nonenal and malondialdehyde) contribute to remodelling of adipose tissue affected by cellulite, as well as fibrotic degeneration of skin, as a consequence of increased stimulation of fibroblasts [7, 8]. In addition, it is well known that the microcirculation is highly responsive to inflammatory processes mediated by free radicals, leading to increased vascular permeability and tissue swelling referred to as edema [9].

Cellulite progression or reduction is studied using different techniques, such as description using various scales,

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palpation, or some instrumental methods, i.e., ultrasonography, magnetic resonance (MRI), thermography, computed tomography (CT), macro-photography, etc [10–16]. The treatment of cellulite varies considerably, with the main approaches being non-invasive and non-surgical, including massage, topical preparations, acoustic wave therapy (AWT), light-based devices, or laser treatment [4, 17]. Topical agents used for cellulite reduction are caffeine, peptides, and some herbal extracts. They are mainly used in order to decrease adipogenesis and increase lipolysis by inducing thermogenesis and microcirculation. On the other hand, retinoids and ascorbic acid could induce signalling pathways of dermal collagen production and increase the hypodermis layer's strength and collagen fibres' thickness [18]. Moreover, some oral herbal products and functional foods have been tested in cellulite condition [2, 5, 19, 20]. In that category, herbal liquid functional or dietary products are of special interest. However, there are only a few scientifically reported studies examining the extent to which they improve the mentioned condition. In our previous study [5], dietary supplementation with organic chokeberry juice showed beneficial effects on cellulite condition in women with a cellulite grade 2 according to the Nurnberger–Muller scale. It is believed that chokeberry juice may help to downgrade cellulite in a way that enhances cellular metabolism, increases collagen synthesis, improves microcirculation and reduces edema [21]. Concerning the chemical composition of chokeberry (*Aronia melanocarpa*), it has been highlighted that anthocyanins are the most important pharmacologically active compounds responsible for its antioxidative, anti-inflammatory, and vasoprotective effects, which could be significant in the case of cellulite [22, 23]. Evidence from experimental and clinical studies indicates that anthocyanins can ameliorate inflammation by decreasing the production of inflammatory markers (IL-6, IL-15 and CRP), improve the antioxidant defence performances of cells on account of the activation enzymes superoxide dismutase and heme oxygenase-1, and upregulate vascular function by increasing flow-mediated dilatation and minimizing capillary permeability and fragility [24]. More recently, the promising potential of cherry juice, originated from tart cherry (*Prunus cerasus*), a low-calorie fruit rich in secondary metabolites–anthocyanins, hydoxycinnamates, and flavan-3-ols, in terms of its antioxidant (stimulation of superoxide dismutase and glutathione peroxidase) and anti-inflammatory properties (inhibition of cyclooxygenase-2) was revealed, and thus could be useful in cellulite treatment [25, 26].

In this study, our aim was to investigate the effects of 32-day oral consumption of dietary supplements based on chokeberry and tart cherry juices (day formula–DF and night formula–NF) enriched with extracts of medicinal plants and edible mushrooms. The studied parameters included ultrasound examinations of the skin and biochemical and anthropometric parameters, which were monitored in 20 women with a cellulite grade of 1–2 according to the Nurnberger–Muller scale (Fig. S1).

Materials and Methods

The material and methods section are reported as a supplementary online document.

Results and Discussion

High-frequency ultrasound measurements In our study, the most significant changes and improvements were recorded by ultrasonography. It represents the most assured method of skin and subcutaneous tissue imaging [27]. Results showed the marked potential of combined DF and NF dietary supplements (DNDS) consumption to improve the morphology of skin and subcutaneous tissue in the areas affected by cellulite, which is more pronounced and faster acting than previously reported results for organic chokeberry juice (OCJ) itself [5]. These findings suggest that DNDS composition shows a synergistic effect, and the activity of separate components is lower compared to the combination used. This is important for adding new evidence to the strategy for both the prevention and treatment of cellulite, since the treatment for cellulite has not been well established, and strong, long-lasting results have not yet been demonstrated [28]. Mlosek et al. also used ultrasonography to study the effects of an anti-cellulite cream containing polyphenol-rich cranberry extract [29]. Although it was a topical application, the treatment mentioned caused a decrease in subcutaneous tissue thickness, the presence of edema, and the length of fascicles.

Thickness of dermis with subcutaneous tissue The characteristics of dermis with subcutaneous tissue were measured using ultrasound before and after 32 days of consumption of DF and NF dietary supplements, and the data are presented in Table 1. A statistically significant reduction in the thickness of the dermis with subcutaneous fat tissue was noticed. The average reduction at the end of the study was 2.49 mm (15.02%). In our previous study [5], treatment with OCJ alone resulted in an average reduction of 1.1 mm (5%) after 45 days of treatment and 2.1 mm (9.6%) after 90 days of treatment. Treatment with DNDS showed a faster effect than OCJ alone, achieving a greater reduction in dermis with subcutaneous tissue thickness in 32 days than OCJ over 90 days. Moreover, supplementation with DNDS showed an efficacy rate of 0.47% reduction per day in dermis with subcutaneous tissue thickness, whereas OCJ

Table 1 Characteristics of dermis and subcutaneous tissue measured by ultrasound

Studied parameters	Day 0	Day 33
Dermis and subcutaneous tissue thickness (mm)	16.58 ± 3.38^{a}	14.09 ± 4.05^{b}
Subcutaneous tissue thickness (mm)	14.77 ± 3.39^{a}	12.65 ± 4.26^{b}
Epidermis thickness (mm)	1.82 ± 0.39^{a}	1.42 ± 0.26^{b}
Dermis and epidermis tissue thickness (mm)	3.63 ± 0.04^{a}	2.87 ± 0.02^{b}
Length of subcutaneous fascicle (mm)	2.70 ± 0.80^{a}	1.73 ± 0.63^{b}

Values are presented as mean value ± SD ($n = 20$); [ab]Means followed by different letters differ significantly ($p < 0.05$)

Table 2 Effects of intervention on subcutaneous edema and presence of TD signals

Studied parameters	Day 0	Day 33
Subjects with edema (n, %)	11/20 (57.9%)	0/20 (0%)
Subjects without TD signals (n, %)	15/20 (78.9%)	2/20 (10.5%)

Values are presented as mean value ± SD ($n = 20$)

alone showed an efficacy rate of 0.11% reduction per day. An improvement was fourfold higher compared to the efficacy rate of OCJ alone.

Thickness of subcutaneous tissue A statistically significant reduction in the thickness of the subcutaneous fat tissue after 32 days of treatment with DNDS was noticed, and the results are presented in Table 1. A marked reduction in the subcutaneous tissue thickness was observed in all subjects, with an average reduction of 2.12 mm (14.34%). Treatment with OCJ alone has been previously reported [5], resulting in an average reduction in the subcutaneous tissue thickness of 0.98 mm (5.0%) after 45 days of treatment and 1.9 mm (9.5%) after 90 days of treatment. Consumption of DNDS showed a faster effect over OCJ alone, achieving a greater reduction in subcutaneous tissue thickness in 32 days than OCJ over 90 days, showing an efficacy rate of 0.45% reduction per day in subcutaneous tissue thickness, whereas OCJ alone showed an efficacy rate of 0.10% reduction per day. An improvement of 4.5 times the efficacy rate of OCJ alone was noticed.

Thickness of epidermis The characteristics of epidermis tissue, measured by ultrasound before and after 32 days of DNDS consumption (Table 1), showed a statistically significant reduction in the thickness of the epidermis after 32 days of treatment. A marked reduction in the epidermis tissue thickness was observed in 94.7% of subjects, with an average reduction of 0.4 mm (21.98%). The effect of OCJ on epidermis tissues was not previously reported.

Thickness of dermis with epidermis The thickness of the dermis in cellulite and its variation under different treatments are controversial. There are studies showing no variations in dermal thickness in patients with or without cellulite, while other studies have recorded decreases in dermal thickness and dermal density in patients with cellulite [28]. According to our study, a statistically significant reduction in the thickness of the dermis with epidermis after 32 days of DNDS consumption was noticed (Table 1), with an average reduction of 0.76 mm (20.94%). In our previous study [5], treatment with OCJ alone resulted in an average reduction of 0.17 mm (6.0%) after 45 days of treatment and 0.31 mm (12.0%) after 90 days of treatment. Consumption of DNDS showed a faster effect over OCJ alone, achieving a greater reduction in dermis and epidermis tissue thickness in 32 days than OCJ over 90 days, showing an efficacy rate of 0.69% reduction *per* day in dermis and epidermis thickness, whereas OCJ alone showed an efficacy rate of 0.13% reduction *per* day. An improvement of over 5 times the efficacy rate of OCJ alone was noticed.

Length and area of fascicles The growth of the fascicles into the dermis is a typical feature of cellulite [5]. According to Mlosek et al. it is one of the most useful parameters to determine whether the applied therapy is effective [29]. The length of the subcutaneous fascicles was measured by ultrasound before and after 32 days of the DNDS consumption (Table 1, Fig S2), and a statistically significant decrease in the length of the fascicles after 32 days of treatment was noticed. A marked reduction was observed in all subjects, with an average reduction of 0.97 mm (35.93%). Treatment with OCJ alone has been previously reported [5], where the length of fascicles was reduced in 97% of the subjects, with an average value of 0.85 mm (29.0%) after 45 days of the study and 1.35 mm (46.0%) after 90 days of the study. Treatment with DNDS showed a faster effect than OCJ alone. DNDS showed an efficacy rate of 1.12% reduction *per* day in fascicle length, whereas OCJ alone showed an efficacy rate of 0.51% reduction *per* day. An improvement of over 2 times was obtained compared to the efficacy rate of OCJ alone. There was no statistically significant difference in the area of the fascicles after 32 days of DNDS treatment, although it was reduced in 17 out of 20 women, and in 5 by approximately 50%. The effect of OCJ on the fascicle area was not reported.

Edema of the dermis Sedentary lifestyle and absence of physical activity are commonly accompanied by muscular hypotonicity, which can slow blood and lymphatic microcirculation, inducing edema in declining areas such as the buttocks [28]. Oxygen diffusion to the skin could be significantly impeded by the development of interstitial edema or any change in skin microvascular network blood flow [30]. In our study, out of 20 subjects, 11 (57.9%) had edema of the dermis at the beginning of the study, and in all of them, the edema disappeared at the end of the 32 days of treatment (Table 2). This edema reduction may be a consequence of microcirculation improvement as a consequence

of anthocyanins in the DNDS combination. Previously reported treatment with OCJ alone [5] resulted in the reduction of edema severity in 37% (6 out of 16) of subjects and the absence of edema in 63% (10 out of 16) of subjects in whom edema was diagnosed at the beginning of the study. At the end of the 90-day study, edema was not observed in any of the subjects included in the study.

Echogenicity and the presence of TD signals Echogenicity refers to the ability of tissues and organs to absorb ultrasound. Liquids have low echogenicity. Therefore, low echogenicity was another sign of the presence of subcutaneous edema in subjects that participated in our study. Of the 20 subjects treated with DNDS, 6 (31.57%) were isoechogenic (normal echogenicity) at the beginning of the study, while 14 (73.68%) were at the end. The effect of OCJ or other herbal treatments on echogenicity was not reported before. TD (tissue doppler) was used to measure the movement of blood in the soft tissues. Skin blood flow plays an important role in maintaining the health of the skin [30]. A higher number of TD signals means a better blood supply. The total number of signals, whether linear or dotted, per unit area or the absence of signals was observed. In this way, the movement of blood in the soft tissues is observed as a reflection of increased or decreased blood supply. According to our results, a statistically significant increase in TD signals in subjects treated with DNDS, which indicates a better blood supply, was recorded after 32 days of treatment (Table 2). At the beginning of the study, 15 of 20 subjects (78.9%) were without recorded TD signals, while after 32 days of treatment, only 2 of 20 (10.5%) were without TD signals. In 7 subjects, an increase of even 3 signals was recorded. Similar testing was not previously reported for oral herbal treatments. The positive effect of DNDS consumption in cellulite condition could be connected with microcirculation improvements. Anthocyanins from different berries were connected with the improvement in vascular function. Bilberry anthocyanins enhanced and promoted arteriolar rhythmic diameter changes known to play a role in microvascular blood flow redistribution and the formation of interstitial fluid [31]. Moreover, phenolics from cranberries, bilberries, and grape seed extracts improved small blood vessel permeability through the repair of vessel damage [32]. Improvement in microcirculation was also one of the mechanisms assumed by Mlosek et al. in their study of anti-cellulite cream formulated with cranberry extract [29]. When it comes to the effects of other herbal products in the clinical studies, Lemaire et al., showed positive effects against cellulite after 56 days oral supplementation with dried and encapsulated melon juice (*Cucumis melo* L.), highly concentrated in SuperOxide Dismutase (SOD B Dimpless®). The improvement was reflected in less visible cellulite on the thighs in supplemented women than in the placebo group, probably due to the induction of endogenous antioxidant enzymes, inhibition of inflammation and oxidative stress, followed by the reduction of fibrosis and adipocyte hypertrophy [33].

Anthropometric and biochemical parameters Data obtained by measuring body weight, body mass index (BMI), fat%, muscle%, visceral fat, and basal metabolism on a medical scale did not show a statistically significant difference at the beginning and end of the 32-day study (Table S4). This outcome confirmed that all of the observed participants made no significant changes in their lifestyles. A similar trend was noticed for all biochemical parameters, which remained within normal limits (Table S4). Since only healthy subjects participated in the study, they were within the normal reference ranges for studied biochemical parameters before entering the study. Reference levels of creatinine, urea, ALT and AST values, as indicators of kidney and liver function, showed that the treatment did not have negative effects on the liver and kidneys during the study. The components included in the composition of the DF and NF products have been used in nutrition and phytotherapy for decades and longer, and there are no significant reports of toxicity. However, absolute confirmation of non-toxicity would require an observation period of at least two years. Sasaki et al. studied the effectiveness of a combination of anti-cellulite gel and LED light [20]. Although they recorded positive effects using ultrasonography, significant changes in thigh circumferences, BMIs, and body weights were not observed.

Conclusions

A positive effect of DNDS 32-day consumption was noticed in cellulite condition regarding the reduction in the thickness of the dermis with subcutaneous fat tissue, subcutaneous fat tissue alone, epidermis alone, and dermis with epidermis, together with the length of the fascicles. Edema in the dermis was not recorded in any subjects at the end of the study, which could be connected with improvements in microcirculation. Moreover, a statistically significant increase in the tissue doppler signals recorded in all subjects indicated better blood supply. Our results showed the marked potential of DNDS in improving the morphology of skin in the regions that are affected by cellulite. The suggested approach might help individuals achieve healthier lifestyle habits that might ease the prolongation of its effects and control the reappearance of cellulite.

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Data Availability The raw data supporting the conclusions of this article will be made available by the authors on request.

Declarations

Ethics Approval The study was conducted in accordance with the Declaration of Helsinki, and approved by the Institutional Ethics Committee of the Institute for Medicinal Plants Research (protocol code 1091 and date of approval 12.04.2023.).

Consent to Participate Informed consent was obtained from all subjects involved in the study.

Competing Interests The authors declare no competing interests.

Conflict of interest The authors declare no conflict of interest.

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